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Quantitative Analysis on Areal Displacement Efficiency in a supercritical CO_2-Water-Quartz Sands System

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Abstract

Micromodels were developed to improve our understanding of how CO_2 flooding and storage efficiency are affected by the wettability in supercritical CO_2-water-quartz sands systems. The micromodel in a pressurized chamber allowed to visualize $scCO_2$ spreading and porewater displacement at high pressure and temperature conditions. CO_2 flooding followed by fingering migration and dewatering followed by formation of residual water were observed. Measurement of areal displacement efficiency at equilibrium decreases as the salinity increases, whereas it increases as the pressure and temperature increases. Experimental results provided fundamental information on migration and distribution of injecting $scCO_2$ under reservoir conditions and CO_2 sequestration progress.

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Keywords: supercritical CO_2, porewater, areal displacement efficiency, micromodel, image analysis

1. Introduction

Carbon dioxide injected in deep geological formations should be safely stored for a geological period through various natural mechanisms including structural trapping, residual trapping, dissolution trapping, and mineral trapping [1]. These trapping mechanisms are affected by various physical and chemical factors such as wettability, surface

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tension, solubility, capillarity, mass transfer, etc. in CO_2-porewater-rock systems, and have direct effects on the CO_2/porewater displacement process and storage efficiency [2]. In order to estimate changes in surface characteristics, many research activities have been conducted on relationships between various geochemical factors such as temperature, pressure, salinity, etc. and surface tension among CO_2-porewater or CO_2-porewater-rock systems [3,4,5]. Of these, experimental studies using a micromodel with porous structures made of transparent materials have been applied in investigating the change in wettability according to geochemical conditions and the effects of surface characteristics of pore structure at pore-scale CO_2 migration through direct observations and image analysis. For making micromodel, silicon wafers and glass plates have been commonly applied. Silicon wafer micromodels are fabricated by engraving designed patterns on the surface of silicon wafers using chemicals, gases, or beams and by fusing a glass plate on it. In addition to the engraving-type, glass plate micromodels include models with a porous structure made of transparent particles such as glass beads or sands between the layers of glass plates [6].

This study aims to conduct supercritical CO_2 ($scCO_2$) injection experiments for visualization of distribution of injected $scCO_2$ and residual porewater in glass-plate micromodels. The results from image analysis were applied in quantitatively investigating the effects of major environmental factors and $scCO_2$ injection methods on porewater displacement process by $scCO_2$ and storage efficiency.

2. Materials and Methods

2.1. Micromodel

Micromodels in this study were fabricated by packing hand-picked, relatively transparent quartz sands with a diameter of 0.60 – 0.85 mm into a long octagonal space created by two glass plates (100 mm × 30 mm × 5 mm) and acryl guards glued with epoxy (Fig. 1). Due to the transparency of the materials used, the micromodel allowed visual observation on imbibition, displacement and drainage processes of fluids under various experimental conditions. The micromodel was further reinforced with epoxy mold to be capable of enduring reservoir conditions with high temperature and pressure. The fabrication of micromodels has been described in detail in Park et al. [7].

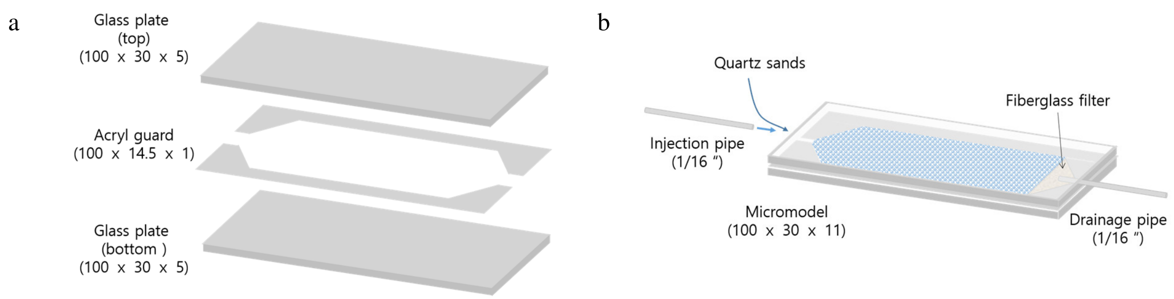

Fig. 1. Making a micromodel; (a) two glass plates and two acryl guards; (b) assembly of a micromodel with glass filter and quartz sands.

The size of the pore structure inside the micromodel was 80 mm × 28 mm × 0.12 mm and the pore volume and the porosity were estimated to 0.68 ± 0.03 ml and 31 ± 1%, respectively.

2.2. Experimental set-up and procedure

The micromodel experimental system was designed to observe migration and distribution of $scCO_2$ in a porous micromodel saturated with porewater and is composed of three components; CO_2 feeding system, confining pressure system, and imaging system (Fig. 2). The CO_2 feeding system was designed to supply $scCO_2$ at experimental